Biology, ecology and status of Iberian ibex *Capra pyrenaica*: a critical review and research prospectus

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ABSTRACT

1. The Iberian ibex *Capra pyrenaica* is endemic to the Iberian Peninsula and of the four subspecies originally recognized, recent extinctions mean that only two now persist. Recent genetic analyses have cast doubt on the generally accepted taxonomy of the species, four subspecies distinguished by coat colour and horn morphology, and propose the distinction of two subspecies based on their mitochondrial DNA sequence polymorphism. These analyses make clear the need for a comprehensive revision that integrates genetic and morphological approaches resulting in a definitive description and differentiation of the subspecies.
2. Studies of ibex behavioural ecology and health status are scarce and generally descriptive. They should be implemented in an integrative way, taking into account ecological requirements of the species, current population status, the presence of other sympatric wild and domestic ungulates, and the type of hunting regime and management attained in their distribution areas.
3. A natural expansion of the species is currently taking place. Ibexes are present and well established in all main mountain ranges of the Spanish Iberian Peninsula, and have recently expanded their range into the north of Portugal. Other authors estimated a total population of more than 50,000 individuals ten years ago, distributed in more than 60,000 km^2, with an average population density of 2.7 ibex/km^2. However, these estimates were obtained prior to the species' recovery from recent epizootics of sarcoptic mange and should be updated. Survey methods, mainly direct count-based methods, should be adjusted to suit mountainous conditions, where it is difficult to estimate accurately the surveyed surface.
4. A series of threats to ibex conservation have been identified, such as population overabundance, disease prevalence and potential competition with domestic livestock and

invasive ungulates, along with negative effects of human disturbance through tourism and hunting.

5. Applied ecological issues focused on the proper management of populations should be prioritized, along with the identification of current threats based on empirical, ecological data obtained from populations living in various ecological conditions in different regions.

Keywords**:** Bovidae, Conservation, Iberian ibex, Iberian Peninsula, Management, Ungulates.

INTRODUCTION

The Iberian ibex *Capra pyrenaica* is endemic to the Iberian Peninsula, and despite its resulting intrinsic value to the European fauna, one of its subspecies *C. p. pyrenaica* became extinct a few years ago (Pérez *et al.*, 2002). The remaining subspecies are, in contrast, undergoing expansion and recovery (e.g. Acevedo, Cassinello & Gortázar, 2007a) and recently a population has become established in Portugal (Moço *et al.*, 2006). Our knowledge of European wild caprids is quite scant, particularly regarding their conservation status and management, and only a few studies of specific aspects of their ecology and behaviour are available in the literature. Many studies of Iberian ibex have been published in local journals or reports, so that their accessibility to an international readership is compromised. Not much is known of the other European wild ibex, the Alpine ibex *Capra ibex*, (see for recent articles Grignolio *et al.*, 2004; Jacobson *et al.*, 2004; von Hardenberg et al., 2004; Lima & Berryman, 2006). The localized distribution of *Capra* spp. might explain the scarcity of studies devoted to this group, particularly when compared to the research addressing other wild ungulates, such as cervids (e.g. Chapman & Chapman, 1975; Clutton-Brock, Guinness & Albon, 1982) and even *Ovis* spp. (e.g. Muller, 1984; Cassinello, 2003). Here, we offer a critical review of work carried out on the species, identifying knowledge gaps and proposing a new research agenda with a view to improving our understanding of the species, leading to a more effective management and conservation actions. We propose carrying out integrative studies, including aspects such as the identification of relevant ibex populations according to their genetic pool, which would lead to a more comprehensive subspecies definition; current population status should be related to regional management policies, i.e., hunting and population translocation regimes; ibex behavioural and ecological studies should be implemented from a conservation perspective, highlighting its role played on the Mediterranean ecosystem, along with behavioural interactions with other ungulate species, and their effect on ibex population dynamics. In sum, ibex research should be relevant to attaining a sensible basis for its management.

Although the term 'Spanish' ibex is commonly used in the literature, we have used 'Iberian' ibex in this review because the species is currently present in both Spain and Portugal (Moço *et al.*, 2006). In reality, the species is endemic to Iberia, as it originally occupied the whole peninsula.

SYSTEMATICS AND TAXONOMY

According to the paleontological studies of Crégut-Bonnoure (1992a, b), two independent migration waves of wild goats took place in Europe. The first one occurred some 300,000 years ago, and led to the origin of the Alpine Ibex, the second took place from the Caucasus around 80,000 years ago leading to the origin of the Iberian ibex. With this scenario, no close relationships would be expected between these European species. However, mtDNA data indicated a much smaller genetic distance between the two European species than between the other existing *Capra* spp. species (Manceau *et al.*, 1999a). Thus, another scenario has been proposed (Manceau *et al.*, 1999a) whereby only one wave of immigration of *Capra* spp. came into Europe, followed by a speciation process that originated the two current species. A paleontological description of a *Capra* spp. specimen found in Germany and dated to around 120,000 years ago (Toepfer, 1934) included characters of both modern taxa, supporting this single wave hypothesis.

Cabrera (1911) originally described four subspecies: *C. p. lusitanica*, which is now extinct but was formerly located in northern Portugal and southern Galicia (Alados, 1985a); *C. p. pyrenaica*, in the Pyrenees, recently extinct (Pérez *et al.*, 2002); *C. p. hispanica*, in the south and east of the Iberian Peninsula; *C. p. victoriae*, mainly in central areas of Spain, such as the Gredos mountain range (Grubb, 2005). This classification is maintained by the IUCN

(Shackleton, 1997), but is questionable because it is only based on coat colour and horn morphology (Cabrera, 1911), two characters that show a high between population variability (Couturier, 1962; Clouet, 1979). Other authors, also drawing on morphological variation, recognize only two different subspecies (Schaller, 1977; Nowak, 1991). Manceau *et al.* (1999b) tested the morphological taxonomy of *C. pyrenaica* with mitochondrial DNA sequence polymorphism. Their genetic study did not support the recognition of the subspecies *C. p. victoriae* and *C. p. hispanica* but was supportive of the distinction between *C. p. pyrenaica* and the former subspecies. Although this study may not be absolutely conclusive, it casts some doubts on the currently accepted taxonomy for the species, which is as follows (Shackleton, 1997):

Species: *Capra pyrenaica*, Schinz (1838)

Subspecies: *C. p. hispanica*, Schimper (1848)
C. p. pyrenaica, Schinz (1838)
C. p. lusitanica, Schlegel (1872)
C. p. victoriae, Cabrera (1911)

Regarding its morphology, data on the European ibex are derived principally from Couturier (1962), Corbet (1966), Hainard (1949), Henrich (1961), Nievergelt (1966), van den Brink (1968) and Walker (1968). They are truly mountainous animals, with large and flexible hooves and short legs, which facilitate them running and leaping on bare rocky, rough and steep slopes (Straus, 1987). Biometric data for the Iberian ibex are scarce and partial (Cabrera, 1914; Rodríguez de la Zubia, 1969; Cabrera, 1985; Escós, 1988; Granados *et al.*, 1997, 2001a). Granados *et al.* (1997, 2001a) studied the basic biometric parameters of ibex from Sierra Nevada and reviewed data from different ibex populations. Data reported by Granados *et al*. (1997) was updated in this study including biometric parameters of Iberian ibexes (n=48) from Albacete population and from Las Batuecas (Losa, 1993) (see Table 1). Generally, body size is larger and weight greater in *C. p. victoriae* than *C. p. hispanica* (e.g., Gonçales, 1982; Granados *et al.*, 1997).

The Iberian ibex shows remarkable sexual dimorphism, males being greater in size and weight with larger horns than females (Fandos, 1991; Granados *et al.*, 1997). Gállego & Serrano (1998) described the postcranial skeleton of the species and showed sex differences in relation to biometry and the ossification process of bones. The maximum level of sexual dimorphism is observed in horn length and basal horn perimeter (Fandos & Vigal, 1993; Granados *et al.*, 2001a). Iberian ibex horns are unique among wild caprids; they curve out and up and then back, inward, and, depending on subspecies, either up again or down (*C. p. victoriae* and *C. p. hispanica*, respectively; Schaller, 1977). Horn shape and fighting technique were studied by Alvarez (1990). Annual horn growth is influenced by the previous year's horn growth, environmental factors but, principally, by age (Fandos, 1995).

Granados *et al.* (2001a) studied growth parameters of Iberian ibex in the Sierra Nevada population. These authors identified faster growth among females, although rates were slower than those obtained in other ibex populations (Fandos, Vigal & Fernández, 1989; Fandos, 1991). This is consistent with the findings of Serrano, Gállego & Pérez's (2004), who showed that female ibex exhibit faster ossification than males, finishing bone development two years before males (Serrano *et al.*, 2006).

Despite this information, a proper comparative morphological analysis of traits including body size and horn size and shape, is lacking. It would be timely to undertake a comprehensive analysis that integrates genetic and morphological approaches to arrive at a definitive description of subspecies that supports their differentiation.

BEHAVIOURAL ECOLOGY

In many social ungulates, particularly those species with pronounced sexual size dimorphism, the two sexes live separately for most of the year and differ in their habitat use. Such sexual segregation has been reported in the Iberian ibex (Alados, 1985b). There are three main hypotheses to explain sexual segregation in ungulates: the predation-risk, forage-selection and activity budget hypotheses. Respectively, they relate sexual segregation either to lactating females' selection of safer habitats; to differing forage digestion efficiency in males and females according to their body size such that males may cope better with nutritionally poor habitats; or, to differing activity budgets between males and females, again related to body size dimorphism (Ruckstuhl & Neuhaus, 2002). These hypotheses are not mutually exclusive, and are subject to serious debate (see, e.g., Bon *et al.*, 2001; Ruckstuhl & Neuhaus, 2002; Bonenfant *et al.*, 2004).

Although no study testing these hypotheses has been carried out on the Iberian ibex, the closely related Alpine ibex shows sexual segregation according to all three hypotheses. Thus, males are preferentially found in riskier (Villaret, Bon & Rivet, 1997) and poorer habitats than females, and both sexes spend a differing percentage of time spent grazing (73% higher female activity; Ruckstuhl & Neuhaus, 2002).

Behaviour of animals should be interpreted with reference to the ecological context where it takes place and it seems that local conditions play an important role in Iberian ibex behaviour that has not yet been incorporated into the evaluation of sexual segregation hypotheses. According to studies carried out on Iberian ibex, the sexes are segregated for most of the year when there are male-only groups and mixed groups of females, juveniles and subadults, whereas during the rutting season adult males and females come together (Granados *et al.*, 2001b). However, this pattern may vary. Thus, in locations such as Cazorla, Segura y Las Villas Natural Park, Sierra Nevada Natural Park, and Gredos Regional Park, ibex live in mixed groups all year, except for August (Gonçales, 1982; Alados & Escós, 1985, 1996). A better knowledge of the factors determining sexual segregation is needed to interpret this pattern of behaviour, which seems not to be so uncommon in other ungulates (K. Ruckstuhl, E. Cameron, pers. comm.). One hypothesis is that there is a relationship between optimal group size and segregation benefits for males and females in any given ungulate population (K. Ruckstuhl, pers. comm.; J. Cassinello pers. obs.). Thus, if a population is sufficiently small, it may not pay them to split, due to sexual segregation premises, if they benefit from larger group size as an antipredator strategy (see Dehn, 1990). Iberian ibex group size formation, on the other hand, seems to be determined by factors such as population density and type of habitat (Granados *et al.*, 2001b), so that a comparative study of sexual segregation behaviour of ibex populations under different ecological conditions might give light on this intriguing issue.

Vigilance behaviour of Iberian ibex has been studied by Alados (1985c). It was determined that lookout individuals are adults placed in the periphery of the herds. Ibexes use alarm calls to alert from potential danger, i.e., the presence of a potential predator. Escape movements are made in an ordered and coordinated manner, mediated by the markedly social hierarchies that characterize all the relations and interactions between herd mates (Alados, 1986).

Seasonal partial-migrations are frequent in species inhabiting regions with pronounced seasonal landscape variability, as it is the case of the Iberian ibex (Fandos & Martínez, 1988). Ibex altitudinal dispersion occurs according to resources availability, e.g., heading to rich, high altitude areas in summer, which are usually covered by snow in winter (e.g., Gonçales, 1982; Escós, 1988; Travesí, 1990).

As for other behavioural studies, the Iberian ibex activity budget has also been studied by several authors. Thus, higher activity rates were detected at first and last day hours in

Cazorla (Alados & Escós, 1988), although this pattern may vary according to temperature variations (e.g., Fandos, 1988). It has also been reported a seasonal variation of home ranges in this species (Escós & Alados, 1992). Home ranges are smaller during the rutting period than in spring, depending on resources quality and availability, and ibex population density (Escós & Alados, 1992; Alados & Escós, 1996). We miss studies on parental investment and sex ratio patterns.

In general, knowing more in detailed how all these patterns of behaviour vary under different environmental conditions, or under the presence of potential competitors, might help in undertaking more proper management practices to preserve ibex populations.

FEEDING HABITS

The feeding ecology of the Iberian ibex has been described in several locations: Sierra Nevada Natural Park (Martínez, 1988a); Cazorla, Segura y Las Villas Natural Park (Garcia-Gonzalez & Cuartas, 1992; Alados & Escós, 1996); Gredos Regional Park (Martínez & Martínez, 1987); Sierra de Tejeda-Almijara (Martínez, 1988b); Tortosa y Beceite National Game Reserve (Martínez, 1994); and Sierra de Montenegro (Palacios, Ibañez & Escudero, 1978). But all these studies are simply descriptive, and no attempt to compare populations has been made so far.

The Iberian ibex is a mixed feeder (browser and grazer), depending on plant availability. Thus, the percentage of each type of resource consumed may vary altitudinally (Martínez, 1994), geographically (Granados *et al.*, 2001b), and seasonally (Garcia-Gonzalez & Cuartas, 1992), the latter being highly influenced by population density (Garcia-Gonzalez & Cuartas, 1992). Some of the species found in its diet include *Agrostis nevadensis*, *Festuca iberica*, *Dactylis glomerata*, *Quercus ilex*, *Phillyrea latifolia* and *Juniperus oxycedrus*

(Martínez, Martínez & Fandos, 1985; Cuartas & Garcia-Gonzalez, 1992; Garcia-Gonzalez & Cuartas, 1992).

Grazing and browsing behaviour vary with location. Thus, grazing predominates in Gredos Regional Park (Martínez, 2001), whereas browsing does in Cazorla, Segura y Las Villas Natural Park, except in spring, when ibex devotes more time to grazing (Martínez *et al*., 1985). Finally, grazing behaviour has been recorded in Sierra Nevada Natural Park during summer (Martínez, 1990). Unfortunately, none of these works have taken into account resource availability.

Also, the Iberian ibex has been included in a few comparative studies of the diets of wild and domestic ungulates (Garcia-Gonzalez & Cuartas, 1989). Autumn diet comparisons of Iberian ibex, domestic goat *Capra hircus*, mouflon and domestic sheep *Ovis aries* showed that sheep are mainly grazers but goats are mainly browsers (Garcia-Gonzalez & Cuartas, 1989).

In sum, while the Iberian ibex shows high feeding plasticity, depending on many ecological circumstances there is only limited understanding of the factors affecting this variation, or of nutritional requirements of ibex and how these differ according to sex and age. No integrating hypotheses have been put forward, and there is a clear need for research to be carried out on sex differences in feeding behaviour, and how this relates to theories of sexual segregation in ungulates (Ruckstuhl & Neuhaus, 2002), and comparisons of resource use by ibex and other wild ungulates living in sympatry, particularly invasive species, such as the aoudad *Ammotragus lervia* (Acevedo *et al.*, 2007b).

EPIDEMIOLOGY AND HEALTH STATUS

Very few studies on health aspects in the Iberian ibex have attempted to relate disease to population dynamics, with the exception of the impact of sarcoptic mange caused by

Sarcoptes scabiei (Pérez *et al.*, 1997; León-Vizcaino *et al.*, 1999). Also, trematode, sporozoan, cestode, nematode and arthropod parasites have been analysed in this species. Two good reviews on this subject, mainly in Andalusian ibex populations, have been recently published. One focuses on pathogens associated with the conjunctiva, external ear canal, as well as reproductive and upper respiratory traits (González-Candela *et al.*, 2006) and the other analyses the whole parasite community (Pérez *et al.*, 2006a). Over a hundred species have been reported as parasites of the Iberian ibex, including viruses, bacteria, fungus, arthropods, protozoa, trematodes, cestodes and nematodes. Bacteria are the most important taxa to the Iberian ibex regarding parasites richness (González-Candela *et al.*, 2006; Pérez *et al.*, 2006a). Nevertheless an arthropod, *Sarcoptes scabiei,* is the most relevant parasite in terms of its impact on population dynamics (Pérez *et al.*, 2006a).

Sarcoptic mange epidemiology in ibex is characterized by periodic fluctuations (outbreaks) with cycles ranging from 10 to 30 years, influenced by a variety of hosts, parasites and external factors (Pérez *et al.*, 1997; Rossi *et al.*, 2007). During the last few decades, several sarcoptic mange epizootics have affected ibex populations from in Cazorla, Segura y Las Villas Natural Park (Fandos, 1991; León-Vizcaino *et al.*, 1999), Sierra Nevada Natural Park (Pérez *et al.*, 1997) and the Sierra Magina range (Palomares & Ruiz-Martínez, 1993). The northern ibex population of Albacete has also recently been reported to be affected by mange (P. Acevedo & C. Gortázar, unpublished data).

When high host densities coincide with limited food availability, high parasite prevalences can be expected due to a loss of fitness and an increase of aggregation at the population level (Acevedo *et al.*, 2005a; Gortázar *et al.*, 2006). This was apparently the case for the sarcoptic mange outbreaks among ibex in Cazorla, Segura y Las Villas Natural Park (León-Vizcaino *et al.*, 1999) which resulted in mortality of over 95% of the population. Nevertheless, the transmission of scabies from domestic sheep and goats to Iberian ibex population has been suggested in the Sierra Nevada population (Pérez *et al.*, 1997), despite there being little evidence. The detrimental effects of population overabundance (Caughley, 1981; Gortázar *et al.*, 2006) can be increased with introductions of exotic and native species, including domestic species (Richardson & Demarais, 1992). These introduced species may have two main effects, an increase in disease prevalence and transmission rates, and the appearance of new diseases (Hofle *et al.*, 2004). A sarcoptic mange episode in free-ranging exotic aoudad in Spain has been recently reported (González-Candela, León-Vizcaíno & Cubero-Pablo, 2004). This exotic species is currently expanding from the south east of the Iberian Peninsula (Cassinello *et al.*, 2004), so that there is a potential risk of it spreading new diseases that could reach the Iberian ibex populations (Acevedo et al. 2007b).

Gastrointestinal and bronchopulmonary nematodes have also been studied in Iberian ibex populations (e.g. Pérez *et al.*, 2003a; Acevedo *et al.*, 2005a). Pérez *et al.* (2003a) analyzed the content of the abomasum and small intestine of ibex from Sierra Nevada Natural Park, and identified 15 species of trichostrongylid nematodes, four of which were found for the first time in this host. Bronchopulmonary nematodes were recently surveyed in the ibex population of Castile-La Mancha (Acevedo *et al.*, 2005a). The infective larval stages in faeces were analysed (Festa-Bianchet, 1991) and 5 genera of bronchopulmonary nematodes were identified (Acevedo *et al.* 2005a). This investigation also supported the importance of density-dependent processes in the transmission of these nematodes in the Iberian ibex since prevalence of these parasites correlated positively with Iberian ibex abundance (Acevedo *et al.* 2005a).

More studies should be undertaken to describe the health status of Iberian ibex populations, especially with regard to viral and bacterial diseases, in order to develop proper population management. Currently, some regional governments are promoting projects on this issue, so that in the near future advances in the epidemiology of ibex diseases are expected.

Finally, haematological parameters were recently reported for the species (Pérez *et al.*, 2003b), and analysed under various stress conditions including the influence of capture methods and captivity (Peinado *et al.*, 1993, 1995), acute haemonchosis (Lavín *et al.*, 1997), infection by *Sarcoptes scabiei* (Pérez *et al.*, 1999) and hunting practises (Pérez *et al.*, 2006b). Blood parameters can provide useful information on health and nutritional status of animals, and are a complementary source of information for monitoring their physiological status (Pérez *et al.*, 2006b).

DISTRIBUTION AND ABUNDANCE

The Iberian ibex used to be widely distributed in all the mountainous regions of the Iberian Peninsula, from the southern coast (Sierra Nevada mountain range) to the Pyrenees. Their populations started to suffer a steady decrease in numbers during the last centuries due to great hunting pressure, together with agricultural development and habitat deterioration, eventually leading to the extinction of two of the four recognized subspecies (Shackleton 1997; Pérez *et al.*, 2002).

The first study of Iberian ibex distribution dates back to 1911 (Cabrera, 1911), but no other work was carried out until several decades later, when a few articles and local reports were published (e.g. de la Peña, 1978; Alados, 1985a, 1997). More recently, status and distribution have been reported by several authors, either in the whole peninsula (Alados, 1997; Granados *et al.*, 2002; Pérez *et al.*, 2002) or in particular geographical areas (Palomares & Ruiz-Martínez, 1993; Pérez, Granados & Soriguer, 1994; Gortázar *et al.*, 2000; Sánchez-Hernández, 2002; Acevedo *et al.*, 2007a). Pérez *et al.* (2002) established a thorough distribution and population trends for the species, concluding that its distribution was fragmented into 51 stable population nuclei covering a more extensive distribution area in comparison to previous studies (Alados, 1997).

Based on some recent studies (Granados *et al.*, 2002; Pérez *et al.*, 2002; Moço *et al.*, 2006; Acevedo *et al.*, 2007a) and some new data, an updated distribution of the Iberian ibex is shown in Fig. 1. New data were obtained from a regional monitoring scheme promoted by Aragón Government, and whose methodological details can be reviewed in Gortázar *et al.* (2007) and Williams *et al.* (2007). The most remarkable differences between this updated distribution and previous reviews are the new localities occupied by the species in Ebro Basin, and its recent colonization and establishment in the north of Portugal, after crossing the Spanish border and settling in Peneda-Gerês National Park (Moço *et al.*, 2006), an area originally inhabited by the extinct *C. p. lusitanica* (Cabrera, 1914). From these results, it can be estimated that the species is now present in more than 60,000 km^2 of the Iberian Peninsula. Although there seems to have been an increase in 14,000 km^2 from the most recent distribution work (Granados *et al.*, 2002), this difference may also reflect a lack of sufficient sampling effort in the areas where ibex have been found only recently.

Ibex distribution is the result of both natural and artificial expansion processes. Most translocations were carried out after 1970, particularly during the 1980s and 90s, the exception is the Maestrazgo area, where ibex were established in 1966 (Pérez *et al.*, 2002, see Fig. 1). Currently, a natural expansion of the populations has been reported both for *C. p. victoriae* and for *C. p. hispanica* subspecies (Pérez *et al.*, 2002; Acevedo *et al.*, 2007a). This expansion has been attributed to their recovery from past mange outbreaks, habitat changes, game management translocations (Gortázar *et al.*, 2000), and probably to a decrease in hunting pressure (Garrido, 2004). A progressive expansion of the Iberian ibex domains has been described for Andalusian populations, suggesting an increment around the centre of their distribution area of 1.8 km per year in Cazorla population (Escós, 1988) and 0.7 km per year in Sierra Nevada population (Alados & Escós, 1996). The ibex dispersive capacity is affected by an increase of densities, lost of traditional agriculture, and habitat improvement (Alados & Escós, 1996).

More than 50,000 Iberian ibexes have been estimated to inhabit the Iberian Peninsula (Pérez *et al.*, 2002), though their status varies among the different nuclei. The average population density was estimated to be 2.7 ibex/km^2, ranging from 0.4 to more than 15.0 ibex/km^2, with most records between 1.2 and 4.4 ibex/km^2 (Pérez *et al.*, 2002; Sánchez-Hernández, 2002; Acevedo *et al.*, 2005a). However, most of this information was recorded before 2000, when sarcoptic mange incidence was quite significant in the study species (Pérez *et al.*, 2002), and given the ibex's current range expansion, we might expect higher average densities in most population nuclei, as have been recently observed in some localities (Acevedo *et al.*, 2007a, d).

The populations of three population nuclei, in Sierra Nevada Natural Park, Cazorla, Segura y Las Villas Natural Park and Gredos Regional Park, represent more than 45% of the Iberian ibexes (Pérez *et al.*, 2002). This may present serious risks for the species, due to the onset of infectious diseases under conditions of overabundance (Gortázar *et al.*, 2006), or the appearance of stochastic events that might cause population declines. Of the two subspecies, *C. p. hispanica* and *C. p. victoriae* the former is more abundant and constitutes more than 80% of the total population (Pérez *et al.*, 2002).

Various methods have been used to estimate the abundance of Iberian ungulates (Alados & Escós, 1996), although their applicability to montane species is limited, since the detectability of individual animals is highly affected by topography. Thus, indirect methods based on searches for signs, such as faeces or tracks, are particularly useful when detection is problematic, as these approaches are cheap, effective and non-invasive (Acevedo *et al.*, 2005a, b, 2007c, in press).

Line transects recording the presence of signs are generally used to derive relative indices of abundance, as they permit comparisons between populations and/or time periods (Acevedo *et al.,* 2005a, 2007c). The detection of signs in plots is also used to estimate relative abundance and population density (Campbell, Swanson & Sales*,* 2004; Acevedo *et al.*, in press), providing defecation and faecal decay rates are known. Finally, direct count methods have been widely applied in ungulates including montane species (Pérez *et al*., 2002; Acevedo *et al*., 2007d). This methodology can be based on linear transects and fixed point counts, and requires the use of specialized software, such as Distance Sampling (Thomas *et al.*, 2006), to estimate population densities.

All these methods require a series of assumptions that in general are not suitable for mountainous habitats, where detectability is often compromised. Some researchers are currently addressing the issue of the application of animal sampling methods in mountainous habitats, particularly as they apply to ungulates (J.M. Pérez, pers. comm.). In our opinion, plot counts should be implemented in Iberian ibex studies, as it is a seasonally independent method that can be easily stratified by habitat type (see Smart *et al.*, 2004; Acevedo *et al.*, in press). Recently, this method has been used satisfactorily in the Iberian red deer in Mediterranean habitats (Acevedo *et al*., in press). Finally, when sampling in mountainous habitats, one of the factors to be taken into account is the establishment of an accurate measure of the sampled area.

CONSERVATION

Populations of wild Caprinae are particularly vulnerable to extinction because of three main factors: genetic isolation, specialised habitat requirements, and low reproductive rate (Shackleton, 1997). However, there are additional factors that interact with these to complicate conservation further. Shackleton (1997) stated that 71% of the species included in the subfamily Caprinae are suffering some type of threat, from which 8% are in a critical situation; 23% threatened; 40% vulnerable; and 28% at lower risk; whereas data from 1% of the species are deficient.

Particularly through continuous hunting pressure, Iberian ibex populations suffered decreases in number during the last centuries, leading to the extinction of *C. p. lusitanica* around 1890 (see Cabrera, 1914). A wild goat conservation program began in 1905 to preserve the last remaining population of *C. p. victoriae*, through the establishment of the National Refuge of Sierra de Gredos as well as a few other reserves created to protect caprids (Cabrera, 1914; Alados, 1997). Although this subspecies eventually recovered, another one has become extinct very recently, *C. p. pyrenaica*, with no males recorded in the wild since 1994 (García-González & Herrero, 1999), and the last known female dying in January 2000 (Pérez *et al.*, 2002). This extinction is particularly unfortunate, as concern was already expressed since the late 1980s and a conservation plan put forward (García-González, Escós & Alados, 1996; García-González & Herrero, 1999), to attempt to recover an already very diminished population, estimated at as few as 6-14 individuals in 1990 (Hidalgo & García-González, 1995). It is probable that conservation efforts came too late, and that the population reached a critical size leading to marked inbreeding depression (Frankham, 1995), as this subspecies showed a high degree of homozygosity (Jiménez *et al.*, 1999). Other hypotheses for its extinction have been postulated, such as resource competition with chamois *Rupicapra pyrenaica* (García-González *et al.*, 1992), infections and diseases caught from domestic livestock, habitat loss and poaching (Hidalgo & García-González, 1995).

Alados (1997) considered that the future of the Iberian ibex depended on developing effective conservation programs and consolidating the existing protected areas. Two main threats to ibex conservation are considered (Alados, 1985a, 1997): increasing presence of domestic livestock, which might transmit diseases to wild ungulates (see examples in

Gortázar *et al.*, 2006) and compete for resources (Acevedo *et al.*, 2007a) and pressure from tourism, an issue currently under study in Sierra Nevada population (R. Soriguer, personal communication). These dual threats can be overcome by establishing management measures to (1) control the number and health status of livestock, (2) restrict or control tourist presence in areas inhabited by ibex, (3) protect large areas from hunting when the population size does not permit sustainable exploitation, and (4) establish proper monitoring of ibex populations.

The European Community included the subspecies *C. p. pyrenaica*, as a priority species, in the Annexes II and IV of the Habitats Directive (The Council of the European Communities, 1992), whereas no other subspecies were considered in this Directive. The last report of the World Conservation Union (IUCN, 2004) considers *C. pyrenaica* to be at Low Risk, but near threatened (LR/nt). However the existing subspecies are categorised differently *C. p. victoriae* is Vulnerable (VU D2), due to the few and small areas it inhabits (Pérez *et al.*, 2002) and *C. p. hispanica* is at Low Risk (LC/cd), where its viability depends on current conservation programmes.

IDENTIFYING GAPS AND PROPOSAL OF A NEW RESEARCH AGENDA

The present overview has shown that current knowledge of the Iberian ibex is focused on some basic aspects of its behavioural ecology, feeding habits and diseases, and that descriptive studies that do not integrate approaches predominate. In former sections we have already advanced a series of lines of research that, to our view, should be implemented.

We appreciate that most studies and empirical information on Iberian ibex is currently produced by regional institutions that carry out periodic surveys on the species' status, mainly in protected areas. It is desirable that this kind of valuable information is not retained in poorly accessible files and local reports, so that promoting contacts between managers, forest rangers and environmental agencies and research institutes should be pursued. This would allow researchers to centralize all the information currently available and design adequate future research projects.

Concerning new lines of research for the Iberian ibex, it is important to identify which aspects of its biology and ecology may prove most valuable in order to establish current threats and assure the conservation of the species, given its current status. We believe that applied ecological studies should not be overlooked, given that the species, although currently expanding its range, may suffer from competition with other ungulate species (e.g., red deer, fallow deer *Dama dama*, aoudad and livestock) and has a clear hunting interest. Previous sarcoptic mange episodes suffered by the species should also indicate caution about its overabundance in some particular areas. In recently colonized localities, its effects on endemic flora should also be analysed. Finally, a clarification of ibex taxonomy, through a multidisciplinary study, that includes historical, biogeographic and genetic analyses, will help in attaining proper conservation and management steps to preserve their whole genetic pool, as some valuable populations may be under threat (e.g. *C. p. victoriae*).

Population management from both conservation and hunting perspectives should be pursued. Currently Iberian ibex trophies may represent an important economic revenue, and biological features, such as factors affecting horn growth (e.g. body condition, immune system, age), and the determination of the genetic breeding value of large- horned males, will help in achieving sustainable wildlife management, adjusting hunting quotas in such a way that removing 'valuable' males is prevented.

A number of primary studies should be undertaken to improve our knowledge of the species and assure its conservation: sampling methods for reliable estimation of abundances and density in poorly accessible mountainous regions; periodic surveys to identify population trends in range; integrated behavioural ecological studies, including veterinary, ethology and trophic ecology approaches; monitor of health status; and ecological modelling to determine population trends and risks.

In summary, the available information on the species, although useful, should be centralised and monitored from scientific criteria. It would be useful to promote periodical meetings of specialists to share their views and establish the necessity of a scientific approach in conservation and management practises.

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REFERENCES

Acevedo, P., Cassinello, J. & Gortázar, C. (2007a) The Iberian ibex is under an expansion trend but displaced to suboptimal habitats by the presence of extensive goat livestock in central Spain. *Biodiversity and Conservation* DOI 10.1007/s10531-006-9032-y.

Acevedo, P., Cassinello, J., Hortal, J. & Gortázar, C. (2007b) Invasive exotic aoudad (*Ammotragus lervia*) as a major threat to native Iberian ibex (*Capra pyrenaica*): A habitat suitability model approach. *Diversity and Distributions* 13: 587–597.

Acevedo, P., Delibes-Mateos, M., Escudero, M.A., Vicente, J., Marco, J. & Gortázar, C. (2005b) Environmental constraints in the colonization sequence of roe deer (*Capreolus capreolus* Linnaeus, 1758) across the Iberian Mountains, Spain. *Journal of Biogeography*, **32**, 1671-1680.

Acevedo, P., Ruiz-Fons, F., Reyes-García A.R. & Gortázar, C. (2007d) *Estudio comparativo de métodos para la estima de la abundancia de ungulados de montaña: la cabra montés*. Proceedings of the VIII Jornadas de la Sociedad Española para la Conservación y Estudio de los Mamíferos, Huelva, Spain.

Acevedo, P., Ruiz-Fons, F., Vicente, J., Reyes-García A.R., Alzaga, V. & Gortázar, C. Estimating red deer abundance in a wide range of management situations in Mediterranean habitats. *Journal of Zoology*, in press.

Acevedo, P., Vicente, J., Alzaga, V. & Gortázar, C. (2005a) Relationship between bronchopulmonary nematode larvae and relative abundances of Spanish ibex (*Capra pyrenaica hispanica*) from Castilla–La Mancha, Spain. *Journal of Helminthology*, **79**, 113-118.

Acevedo, P., Vicente, J., Hofle, U., Cassinello, J., Ruiz-Fons, F. & Gortázar, C. (2007c) Estimation of European wild boar relative abundance and aggregation: a novel method in epidemiological risk assessment. *Epidemiology and Infection*, **135**, 519-527.

Alados, C.L. (1985a) Distribution and status of the Spanish ibex (*Capra pyrenaica*, Schinz). In: *The biology and management of mountain ungulates* (Ed. by S. Lovari), pp. 204-211. Croom-Helm, Beckenham London.

Alados, C.L. (1985b) Group size and composition of the Spanish ibex (*Capra pyrenaica*, Shinz). In: *The biology and management of mountain ungulates* (Ed. by S. Lovari), pp. 137-147. Croom-Helm, Beckenham London.

Alados, C.L. (1985c) An analysis of vigilance in the Spanish ibex (*Capra pyrenaica*). *Zeitschrift für Tierpsychologie*, **68**, 58-64.

Alados, C.L. (1986) Aggressive behaviour, sexual strategies and their relation to age in male Spanish ibex (*Capra pyrenaica*). *Behaviour Processes*, **12**, 145-158.

Alados, C.L. (1997) Status and distribution of Caprinae by region. Spain. In *Wild sheep and goats and their relatives* (Ed. by D.M. Shackleton), pp. 125-130. IUCN, Cambridge.

Alados, C.L. & Escós, J. (1985) La cabra montés de las sierras de Cazorla y Segura. Una introducción al estudio de sus poblaciones y comportamiento. *Naturalia Hispanica*, **28**, 36 pp.

Alados, C.L. & Escós, J. (1988) Alarms calls and fligh behaviour in Spanish ibex (*Capra pyrenaica*). *Biology of Behaviour*, **13**, 11-21.

Alados, C.L. & Escos, J. (1996) *Ecología y comportamiento de la cabra montés. Consideraciones para su gestión*. Monografías del Museo Nacional de Ciencias Naturales. Consejo Superior de Investigaciones Científicas, Madrid.

Alvarez, F. (1990) Horns and fighting in male Spanish ibex, *Capra pyrenaica*. *Journal of Mammalogy*, **71**, 608-616.

Bon, R., Rideau, C., Villaret, J.-C. & Joachim, J. (2001) Segregation is not only a matter of sex in Alpine ibex, *Capra ibex ibex*. *Animal Behaviour*, **62**, 495-504.

Bonenfant, C., Loe, L.E., Mysterud, A., Langvatn, R., Stenseth, N.C., Gaillard, J.M. & Klein, F. (2004) Multiple causes of sexual segregation in European red deer: enlightenments from varying breeding phenology at high and low latitude. Proceedings of the Royal Society of London, Series B, **271**, 883-892.

Cabrera, A. (1911) The subspecies of the Spanish ibex. *Proceeding of the Zoological Society London*, 963-977.

Cabrera, A. (1914) *Fauna Ibérica: Mamíferos*. Museo Nacional de Ciencias Naturales, Madrid.

Cabrera, E. (1985) La cabra montés. In: *Sierra Nevada y la Alpujarra* (Ed. By M Ferrer), pp. 211-247. Granada.

Campbell., D., Swanson, G.M. & Sales, J. (2004) Comparing the precision and cost-effectiveness of faecal pellet group count methods. *Journal of Applied Ecology*, **41**, 1185-1196

Cassinello, J. (2003) Muflón - *Ovis aries*. In: *Enciclopedia virtual de los vertebrados españoles* (Ed. by L.M. Carrascal & A. Salvador). Museo Nacional de Ciencias Naturales, Madrid. http://vertebradosibericos.org/

Cassinello, J., Serrano, E., Calabuig, G. & Pérez, J.M. (2004) Range expansion of an exotic ungulate (*Ammotragus lervia*) in southern Spain: ecological and conservation concerns. *Biodiversity and Conservation*, **13**, 851-866.

Caughley, G. (1981) Overpopulation. In: *Problems in management of locally abundant wild mammals* (Ed. by P.A. Jewell, S. Holt & D. Hart), pp. 7-19. Academic, New York.

Chapman, D. & Chapman, N. (1975) *Fallow deer. Their history, distribution and biology*. Terence Dalton Limited, Suffolk.

Clouet, M. (1979) Note sur la systématique du bouquetin d'Espagne. *Bulletin de Society Historie Naturelle de Toulouse*, **115**, 269-277.

Clutton-Brock, T., Guinness, F.E. & Albon, S.D. (1982) *Red deer: Behavior and ecology of two sexes*. Edinburgh University Press, Edinburgh.

Corbet, G.B. (1966) *The terrestrial mammals of western Europe*. Dufour Editions, Philadelphia.

Couturier, M. (1962) *Le bouquetin des Alpes*. Grenoble.

Crégut-Bonnoure, E. (1992a) Les Caprinae (Mammalia, Bovidae) du Pléistocène d'Europe : Intérêt biostratigraphique, paléoécologique et archéozoologique. *Mém Soc Géol France*, **160**, 85-93.

Crégut-Bonnoure, E. (1992b) Intérêt biostratigraphique de la morphologie dentaire de Capra (Mammalia, Bovidae). *Annales Zoologici Fennici*, **28**, 273-290.

Cuartas, P. & Gracia-Gonzalez, R. (1992) *Quercus ilex* browse utilization by Caprini in Sierra de Cazorla and Segura (Spain). *Vegetatio*, **99/100**, 317-330.

de la Peña, J. (1978) *La cabra montés en España*. Congreso Internacional de la Caza, Suiza.

Dehn, M.M. (1990). Vigilance for predators: detection and dilution effects. *Behavioral Ecology and Sociobiology*, **26**, 337-342.

Escós, J. (1988) Estudio sobre la ecología y etología de la cabra montés (*Capra pyrenaica hispanica* Schimper, 1848) de las Sierras de Cazorla y Segura y Sierra Nevada oriental. Phd Thesis, Universidad de Granada, 603 pp.

Escós, J. & Alados, C. (1992) The home-range of Spanish ibex in spring and fall. *Mammalia*, **56**, 57-63.

Fandos, P. (1988) Differences saisonnières dans la répartition des activités quotidiennes du bouquetin, *Capra pyrenaica*, de Cazorla. *Mammalia*, **52**, 3-9.

Fandos, P. (1991) *La cabra montés (*Capra pyrenaica*) en el Parque Natural de Cazorla, Segura y Las Villas*. Colección Técnica, ICONA, Madrid.

Fandos, P. (1995) Factors affecting horn growth in male Spanish ibex (*Capra pyrenaica*). *Mammalia*, **59**, 229-235.

Fandos, P. & Martínez, T. (1988) Variación en la agregación y distribución de la cabra montés (*Capra pyrenaica* Schinz, 1838) detectado por un muestreo de excrementos. *Doñana Acta Vertebrata*, **15**, 133-140.

Fandos, P. & Vigal, C.R. (1988) Body weight and horn length in relation to age of the Spanish wild goat. *Acta Theriologica*, **33**, 239-242.

Fandos, P. & Vigal, C.R. (1993) Sexual dimorphism in size of the skull of Spanish ibex *Capra pyrenaica*. *Acta Theriologica*, **38**, 103-111.

Fandos, P., Vigal, C.R. & Fernández, J.M. (1989) Weigth estimation of Spanish ibex, *Capra pyrenaica*, and chamois, *Rupicapra rupicapra* (Mammalia, Bovidae). *Zeitschrift fur Saugetierkunde*, **54**, 239-242.

Festa-Bianchet, M. (1991) Numbers of lungworms larvae in faeces of bighorn sheep: yearly changes, influence of host sex, and effects on host survival. *Canadian Journal of Zoology*, **69**, 547-554.

França, C. (1917) Le buquetin du Gerz (*Capra lusitanica*). *Arq. Universidade Lisboa*, **4**, 19-54.

Frankham, R. (1995) Effective population size/adult population size ratios in wildlife: a review. *Genetical Research*, **66**, 95-107.

Gállego, L. & Serrano, E. (1998) *Ecosistema* Capra pyrenaica*: diferencias sexuales en el esqueleto postcraneal*. Bilbilis, Palma de Mallorca.

García-Gonzalez, R. & Cuartas, P. (1989) A comparison of the diets of the wild goat (*Capra pyrenaica*), domestic goat (*Capra hircus*), mouflon (*Ovis musimon*) and domestic sheep (*Ovis aries*) in the Cazorla mountain range. *Acta Biologica Montana*, **9**, 123-132.

García-Gonzalez, R. & Cuartas, P. (1992) Feeding strategies of Spanish wild goat in the Cazorla Sierra (Spain). *Ongules/Ungulates*, **91**, 167-170.

García-González, R., Escós, J. & Alados, C.L. (1996) Una población en peligro: El bucardo. In: Ecología y Comportamiento de la Cabra Montés Consideraciones Para Su Gestión (Ed. by C.L. Alados & J. Escós), pp. 105–120. Museo Nacional de Ciencias Naturales, Madrid, Spain.

García-González, R. & Herrero, J. (1999) El bucardo de los Pirineos: historia de una extinción. Galemys, **11**, 17–26.

García-González, R., Hidalgo, R., Ameztoy, J.M. & Herrero, J. (1992) Census, population structure and habitat use of a chamois population in Ordesa N. P. living in sympatry with the Pyrenean wild goat. In: *Ongulés/Ungulates 91* (Ed. by F. Spitz, G. Janeau, G. Gonzalez, & S. Aulagnier), pp. 321-325. SFEPM-IRGM, Paris-Toulouse.

Garrido, J.L. (2004) Aprovechamientos por especies y autonomías. II Máster en Conservación y Gestión de los Recursos Cinegéticos. Ciudad Real, marzo 2004. Unpublished report.

Gonçales, G. (1982) Eco-ethologie du bouquetin en Sierra de Gredos. *Acta Biologica Montana*, **1**, 177-215.

González-Candela, M., Cubero-Pablo, M.J., Martín-Atance, P. & León-Vizcaíno, L. (2006) Potential pathogens carried by Spanish ibex (*Capra pyrenaica hispanica*) in southern Spain. *Journal of Wildlife Diseases*, **42**, 325-334.

González-Candela, M., León-Vizcaíno, L. & Cubero-Pablo, M.J. (2004) Population effects of sarcoptic mange in Barbary sheep (*Ammotragus lervia*) from Sierra Espuña Regional Park, Spain. *Journal of Wildlife Diseases*, **40**, 456-465.

Gortázar, C., Acevedo, P., Ruiz-Fons, F. & Vicente, J. (2006) Disease risks and overabundance of game species. *European Journal of Wildlife Research*, **52**, 81-87.

Gortázar, C., Herrero, J., Villafuerte, R. & Marco, J. (2000) Historical examination of the distribution of large mammals in Aragón, Northeastern Spain. *Mammalia*, **61**, 411-422.

Gortázar, C., Millán, J., Acevedo, P., Marco, A. Escudero, M.A., Marco, J. & Fernández de Luco, D. (2007) A large-scale survey of brown hare *Lepus europaeus* and Iberian hare *L. granatensis* populations at the limit of their ranges. *Wildlife Biology,* **13**, 244-250.

Granados, J.E., Fandos, P., Márquez, F.J., Soriguer, R.C., Cirrosa, M. & Pérez, J.M. (2001a) Allometric growth in the Spanish ibex, *Capra pyrenaica*. *Folia Zoologica*, **50**, 19-23.

Granados, J.E., Pérez, J.M., Márquez, F.J., Serrano, E., Soriguer, R.C. & Fandos, P. (2001b) La cabra montés (*Capra pyrenaica*, Schinz 1838). *Galemys*, **13**, 3-37.

Granados, J.E., Pérez, J.M., Soriguer, R.C., Fandos, P. & Ruiz-Martínez, I. (1997) On the biometry of the Spanish ibex *Capra pyrenaica*, from Sierra Nevada (Southern Spain). *Folia Zoologica*, **46**, 9-14.

Granados, J.E., Soriguer, R.C., Pérez, J.M., Fandos P. & García-Santiago, J. (2002) La cabra montés. In: *Atlas de los mamíferos terrestres de España* (Ed.by L.J. Palomo & Gisbert, J.), pp. 326-329. Dirección General de Conservación de la Naturaleza, SECEM, SECEMU, Madrid.

Grignolio, S., Rossi, I., Bassano, B., Parrini, F. & Apollonio, M. (2004) Seasonal variations of spatial behaviour in female Alpine ibex (*Capra ibex ibex*) in relation to climatic conditions and age. *Ethology Ecology & Evolution*, **16**, 255-264.

Grubb, P. (2005) Order Artiodactyla. In: *Mammal species of the world: A taxonomic and geographic reference*, 3rd ed. (Ed. by D.E. Wilson & D.M. Reeder), pp. 637-722. The Johns Hopkins University Press, Baltimore, Maryland.

Hainard, R. (1949) *Les Mammifères Sauvages d'Europe II*. Neuchâtel: Delachaux et Niestlé.

Henrich, P. (1961) *Caza Mayor*. Barcelona: Sintes.

Hidalgo, R. & García-González, R. (1995) Remnant Pyrenean wild goat population in Ordesa and Monte Perdido National Park, Pyrénées (Spain). *Caprinae News IUCN*, **8/9**, 9-13.

Hofle, U., Vicente, J., Nagore, D., Hurtado, A., Pena, A., de la Fuente, J. & Gortázar, C. (2004) The risks of translocating wildlife: Pathogenic infection with *Theileria* sp. and *Eleaphora elaphi* in a imported red deer. *Veterinary Parasitology*, **126**, 387-395.

IUCN (2004) 2004 IUCN red list of threatened species. <www.redlist.org>. Downloaded on 26 January 2007.

Jacobson, A.R., Provenzale, A., von Hardenberg, A., Bassano, B. & Festa-Bianchet, M. (2004) Climate forcing and density dependence in a mountain ungulate population. *Ecology*, **85**, 1598-1610.

Jiménez, N., Folch, J., Fernández-Arias, A., Guiral, J. & Sánchez, A. (1999) Estudio genético mediante marcadores microsatélites de las poblaciones de cabra montés. *ITEA*, Vol. Extra **20**, 300-302.

Lavín, S. Marco, I., Rossi, L., Meneguz, P.G. & Viñas, L. (1997) Haemonchosis in Spanish ibex. *Journal of Wildlife Diseases*, **33**, 641-651.

León-Vizcaino, L., de Ybanez, M.R.R., Cubero, M.J., Ortiz, J.M., Espinosa, J., Perez, L., Simon, M.A. & Alonso, F. (1999) Sarcoptic mange in Spanish ibex from Spain. *Journal of Wildlife Diseases*, **35**, 647–659.

Lima, M. & Berryman, A. (2006) Predicting nonlinear and non-additive effects of climate: the Alpine ibex revisited. *Climate Research*, **32**, 129-135.

Losa, J. (1993) *El macho montés: exposición monográfica de una pieza de caza*. Junta de Castilla y León, Valladolid.

Manceau, V., Crampe, J.P., Boursot, P. & Taberlet, P. (1999b) Identification of evolutionary significant units in the Spanish wild goat *Capra pyrenaica* (Mammalia, Artiodactyla). *Animal Conservation*, **2**, 33-39.

Manceau, V., Deprés, L., Bouvet, J. & Taberlet, P. (1999a) Systematics of the Genus *Capra* inferred from mitochondrial DNA sequence data. *Molecular Phylogenetics and Evolution*, **13**, 504-510.

Martínez, T. (1988a) Utilisation de l'analyse micrographique de fèces pour l'étude du régime alimentarie du boutequin de la Sierra Nevada (Espagne). *Mammalia*, **52**, 46.

Martínez, T. (1988b) Données sur l'alimentation du bouquetin d'Espagne (*Capra pyrenaica*) dans la Sierra de Tejeda (Granada). *Mammalia*, **52**, 2.

Martínez, T. (1994) Hábitos alimentarios de la cabra montés (*Capra pyrenaica*) en zonas de distinta altitud en los puertos de Tortosa y Beceite. Referencia a la dieta de machos y hembras. *Doñana Acta Vertebrata*, **21**, 25-37.

Martínez, T. (2001) The feeding strategy of Spanish ibex (*Capra pyrenaica*) in the northern Sierra de Gredos (central Spain). *Folia Zoologica*, **50**, 19-33.

Martínez, T. & Martínez, E. (1987) Diet of Spanish wild goat, *Capra pyrenaica* in spring and summer at the Sierras de Gredos, Spain. *Mammalia*, **35**, 547-558.

Martínez, T., Martínez, E. & Fandos, P. (1985) Composition of the food of the Spanish wild goat in Sierras de Cazorla and Segura, Spain. *Acta Theriologica*, **30**, 461-494.

Martínez, T. (1990) Régimen alimentario de la cabra montés (*Capra pyrenaica*) en la zona alpina de Sierra Nevada durante los meses de julio y agosto. *Ecología*, **4**, 177-183.

Moço, G., Guerreio, M., Ferreira, A.F., Rebelo, A., Loureiro, A., Petrucci-Fonseca, F. & Pérez, J.M. (2006) The ibex *Capra pyrenaica* returns to its former Portuguese range. Oryx, **40**, 351-354.

Muller, H. (1984). *Sheep*. Barron's, New York.

Nievergelt, B. (1966) *Der Alpensteinbock in seinem Lebensraum*. Hamburg, Berlin: Verlag Paul Parey.

Nowak, R.N. (1991) *Mammals of the World*. (5 edn). The Johns Hopkins University Press, Baltimore and London.

Palacios, F., Ibañez, Z. & Escudero, J. (1978) Algunos datos sobre la alimentación de la cabra montés ibérica (*Capra pyrenaica*) y notas sobre la fauna de Montenegreto (Tarragona). *Boletín de la Estación Central de Ecología*, **7**, 56-66.

Palomares, F. & Ruiz-Martínez, I. (1993) Status and conservation perspectives for the Spanish ibex population of Sierra Mágina Natural Park, Spain. *Zeitschrift fur Jagdwissenschaft*, **39**, 87-94.

Peinado, V.I., Fernández, A., Viscor, G. & Palomeque, J. (1993) Haematology of Spanish ibex (*Capra pyrenaica hispanica*) restrained by physical or chemical means. *Veterinary Record*, **132**, 580-583.

Peinado, V.I., Fernández, A., Zabala, J.L.G. & Palomeque, J. (1995) Effect of captivity on the blood composition of Spanish ibex (*Capra pyrenaica hispanica*). *Veterinary Record*, **137**, 588-591.

Pérez, J.M., González, F.J., Granados, J.E., Pérez, M.C., Fandos, P., Soriguer, R.C. & Serrano, E. (2003b) Hematologic and biochemical reference intervals for Spanish ibex. *Journal of Wildlife Diseases*, **39**, 209-215.

Pérez, J.M., González, F.J., Serrano, E., Granados, J.E., Fandos, P., Carro, F. & Soriguer, R.C. (2006b) Is blood collected from shot Iberian ibex (*Capra pyrenaica*) useful for monitoring their physiological status? *European Journal of Wildlife*, **52**, 125-131.

Pérez, J.M., Granados, J.E., González, F.J., Ruiz-Martínez, I. & Soriguer, R.C. (1999) Hematologic parameters of the Spanish ibex (*Capra pyrenaica*). *Journal of Zoo and Wildlife medicine*, **30**, 550-554.

Pérez, J.M., Granados, J.E., Pérez, M.C., Márquez, F.J., Ferroglio, E. & Rossi, L. (2003a) A survey of the gastrointestinal nematodes of Spanish ibex (*Capra pyrenaica*) in a high mountain habitat. *Veterinary Parasitology*, **89**, 315-318.

Pérez, J.M., Granados, J.E. & Soriguer, R.C. (1994) Population dynamic of the Spanish ibex *Capra pyrenaica* in Sierra Nevada Natural Park (southern Spain). *Acta Theriologica*, **39**, 289-294.

Pérez, J.M., Granados, J.E., Soriguer, R.C., Fandos, P., Marquez, F.J. & Crampe, J.P. (2002) Distribution, status and conservation problems of the Spanish Ibex, *Capra pyrenaica* (Mammalia : Artiodactyla). *Mammal Review*, **32**, 26-39.

Pérez, J.M., Meneguz, P.G., Dematteis, A., Rossi, L. & Serrano, E. (2006a) Parasites and conservation biology: The ‘ibex-ecosystem’. *Biodiversity and Conservation*, **15**, 2033–2047.

Pérez, J.M., Ruiz-Martínez, Granados, J.E., Soriguer, R.C. & Fandos, P. (1997) The dynamics of sarcoptic mange in the ibex population of Sierra Nevada in Spain. Influence of climatic factors. *Journal of Wildlife Research*, **2**, 86-89.

Richardson, M.L. & Demarais, S. (1992) Parasites and condition of coexisting populations of white-tailed and exotic deer in southcentral Texas. *Journal of Wildlife Diseases*, **28**, 485–489.

Rodríguez de la Zubia, M. (1969) *La cabra montés de Sierra Nevada*. Documentos Técnicos, serie cinegética 1, Ministerio de Agricultura, Madrid.

Rossi, L., Fraquelli, C., Vesco, U., Permunian, R., Sommavilla, G.M., Carmignola, G., Da Pozzo, R. & Meneguz, P.G. (2007). Descriptive epidemiology of a scabies epidemic in chamois in the Dolomite Alps, Italy. *European Journal of Wildlife Research*. DOI 10.1007/s10344-006-0067-x

Ruckstuhl, K.E. & Neuhaus, P. (2002) Sexual segregation in ungulates: a comparative test of three hypotheses. *Biological Review*, **77**, 77-96.

Sanchez-Hernandez, L. (2002) Characteristics of the Iberian wild goat *Capra pyrenaica hispanica* of Madrona and Sierra Quintana (Spain). The success of private management. *Pirineos*, **157**, 169-180.

Schaller, G.B. (1977) *Mountain monarchs: wild sheep and goats of the Himalaya*. The Univeristy of Chicago Press.

Schimper, H.R. (1848) *Descripción abreviada de* Capra hispanica. C.R. Académie Scienfic. Paris XXVI 10.

Schinz, R. (1838) *Descripción de* Capra pyrenaica. Nouveaux memoires de la Societe Helvetique d'histoire Naturell. Neuchatel.

Schlegel, H. (1872) *De dierentuin van het Koninklijk Zoologisch Genootschap Natura Artis Magistra te Amsterdam zoologisch geschetst*. Gebr. Van Es., Ámsterdam.

Serrano, E., Gállego, L. & Pérez, J.M. (2004) Ossification of the appendicular skeleton in the Spanish ibex *Capra pyrenaica* Schinz, 1838 (Artiodactyla: Bovidae), with regard to determination of age. *Anatomia Histologia Embryologia-Journal of Veterinary Medicine Series C*, **33**, 33–37.

Serrano, E., Pérez, J.M., Christiansen, P. & Gállego, L. (2006) Sex-difference in the ossification rate of the appendicular skeleton in *Capra pyrenaica* Schinz, 1838, and its utility in the sex identification of long bones. *Anatomia Histologia Embryologia-Journal of Veterinary Medicine Series C*, **35**, 69-75.

Shackleton, D.M. (1997) *Wild Sheep and Goats and their Relatives: Status Survey and Conservation Action Plan for Caprinae*. IUCN, Gland. Switzerland.

Smart, J.C.R., Ward, A.I. & White, P.C.L. (2004) Monitoring woodland deer populations in the UK: an imprecise science. *Mammal Review*, **34**, 99-114.

Straus, L.G. (1987) Upper Paleolithic Ibex hunting in Southwest Europe. *Journal of Archaelogical Science*, **14**, 163-178.

The Council of the European Communities (1992) Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora. *Official Journal L*, **206**, 7-50.

Toepfer, V. (1934) Ein diluviales Steinbockgehörn aus Thüringen. *Paläontologie Zeitschrift*, **16**, 276-281.

Thomas, L., Laake, J.L., Strindberg, S., Marques, F.F.C., Buckland, S.T., Borchers, D.L., Anderson, D.R., Burnham, K.P., Hedley, S.L., Pollard, J.H., Bishop, J.R.B. & Marques, T.A. (2006) Distance 5.0. Release "x"1. Research Unit for Wildlife Population Assessment, University of St. Andrews, UK. http://www.ruwpa.st-and.ac.uk/distance/

Travesí, R. (1990) La cabra montés en el macizo occidental de Sierra Nevada. *Vida Silvestre*, **68**, 61-65.

van den Brink, F.H. (1968) *A field guide to the mammals of Britain and Europe*. Houghton Mifflin, Boston.

Villaret, J.C., Bon, R. & Rivet, A. (1997). Sexual segregation of habitat by the alpine ibex in the French Alps. *Journal of Mammalogy*, **78**, 1273-1281.

von Hardenberg, A., Bassano, B., Arranz, M.P.Z. & Bogliani, G. (2004) Horn growth but not asymmetry heralds the onset of senescence in male Alpine ibex (*Capra ibex*). *Journal of Zoology*, **263**, 425-432.

Walker, E. (1968) *Mammals of the World*. Johns Hopkins Press., Baltimore.

Williams, D., Acevedo., P., Gortazar, C., Escudero., M.A., Labarta, J.L., Marco, J. & Villafuerte, R. (2007) Hunting for answers: rabbit (*Oryctolagus cuniculus*) population trends in northeastern Spain. *European Journal of Wildlife Research*, **53**, 19-28.

Figure 1. Current estimated distribution of the Iberian ibex *Capra pyrenaica.* Data come from Granados *et al.*, 2002; Pérez *et al.*, 2002; Moço *et al.*, 2006 and Acevedo *et al.*, 2007a. Present study data are shown in black squares Dotted lines delimit boundaries of the provinces. Arrows indicate translocations from labelled populations (Pérez *et al.*, 2002). The distribution of the two subspecies is represented by the discontinuous line, *C. p. victoriae* in the north-west, and *C. p. hispanica* in the south and east. Presence data refer to UTM grid cells of 10 x 10 km^2.

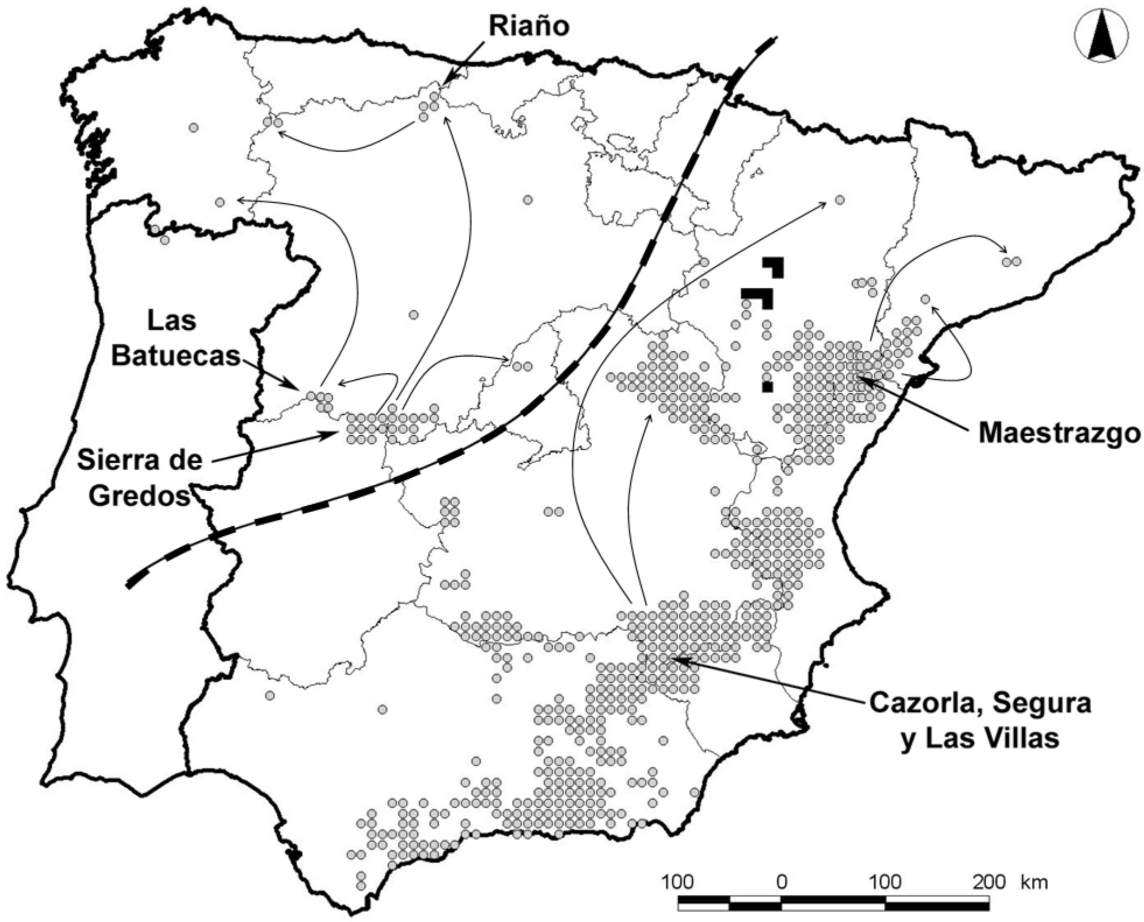

Table 1. Biometric data reported from different ibex populations (updated from Granados *et al.*, 1997). Male - female values are shown. Length is in centimetres and weight in kilograms. "?" indicates the absence of data.

	Body weight	Cross height	Body length	Horn length	Basal horn perimeter
Albacete					
Present study	58.4-35.0	?-?	?-?	55.8-?	23.2-?
Sierra Nevada					
(Granados *et al.*, 1997)	50.4-31.3	79.3-69.0	108.6-96.9	47.5-13.9	20.7-9.7
(Cabrera, 1914)	?-?	65.5-?	121.0-?	?-?	?-?
(Cabrera, 1985)	?-?	84.1-?	144.0-?	?-?	?-?
(Escós, 1988)	65.0-?	65.0-?	132.0-116.0	63.8-19.2	22.7-?
Cazorla					
(Escós, 1988)	?-?	67.2-66.2	128.1-118.2	48.8-13.5	20.1-8.6
(Fandos, 1991)	54.9-31.5	81.1-69.7	132.1-112.8	76.0-17.1	?-?
Gredos					
(Cabrera, 1914)	?-?	70.0-?	135.5-?	73.2-16.5	24.4-10.0
(Gonçales, 1982)	90.0-40.0	75.0-65.0	155.0-115.0	?-?	?-?
(Fandos & Vigal, 1988)	61.9-36.8	?-?	?-?	83.7-28.7	?-?
Las Batuecas					
(Losa, 1993)	78.0-41.0	89.0-76.0	146.0-130.0	74.0-17.0	26.0-11.5
Sierra Morena					
(Cabrera, 1914)	?-?	?-?	?-?	85.0-?	?-?
Pirineos Aragón					
(Cabrera, 1914)	?-?	75.0-?	148.0-?	91.0-26.8	23.0-14.0
C. p. lusitanica					
(Cabrera, 1914)	?-?	74.5-?	142.0-?	42.0-18.0	20.0-?
(França, 1917)	?-?	69.5-?	140.0-?	?-?	?-?
Pirineos-Gredos					
(Couturier, 1962)	75.0-37.5	?-?	?-?	?-?	?-?